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Metamaterial-Inspired-Square Ring Resonator Structure using MIMO Antenna for Multi band Wireless Communication Networks and Fifth Generation Applications

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Abstract: A Metmaterial construction is to reduce the mutual coupling between the closely spaced microstirp patch antenna elements is given in this research. The proposed antenna two monopoles of various sizes are place in parallel with stub 3.5mm thickness used for good impedance. An electrically thin substrate was coupled by a parallel line, and the feed was connected to a tuning stub. MIMO antenna consisting of two port components is positioned in parallel to one another, with an edge to edge spacing of (6mm) maintain the meta material structure between the MIMO Parts results in a10 dB increase the isolation. About -28 dB of isolation is attained with the suggested configuration. The suggested antenna is a strong contender for MIMO applications because of its low ECC, high gain, minimal channel capacity loss, and extremely low mutual coupling between components. Proposed system has the following advantages: low profile, broad bandwidth, high gain (>8 dB), improved isolation (28 dB), low channel capacity loss (CCL) (<0.05) and envelope correlation coefficient (<0.0001), as well as high diversity gain (DG) (>9.99 dB). Good agreement is found between the simulated and measured data, confirming the system performance experimentally. These characteristics highlight the system's suitability for 5G wireless networks.

Keywords: *Monopoles antenna, Wireless applications, Metamertial, Isolation, 5G.*

1. Introduction

This paper presents the design and development of a dual-band and dual-polarized two port multiple-input-multiple-output (MIMO) The channel capacity of a multiple input multiple output system is primarily determined by its bandwidth and signal to noise ratio. The UWB's low power needs systems in wireless high data rate have attracted a lot of interest [1]. Ultra-wideband (UWB) frameworks can use an unlicensed frequency spectrum of 3.1–10.6 GHz, according to the Federal Communication Commission [2]. The restricted channel capacity of the UWB system is one of the elements that affects its output. In order to provide improved service to a greater number of customers while using the restricted frequency, transmission power and bandwidth are important subjects in the wireless communication sector [3]. Some have tried to enhance the operable scope by operating in the dynamic spectrum allocation mode, known as spectrum cooperation [4], or to distribute the operable spectrum in a way that is more efficient [5-7].

1.1. Antenna Structure Design

The antenna is made up of two printed (etched) monopoles that are placed on the same side of an electrically thin substrate and have varying lengths. A series microstrip line with a tuning stub connects the monopoles. In this design, the comparatively cheap substrate FR4 is employed. The rear of the substrate is printed with a ground plane, whose width and length match the substrate's width and the microstrip feedline's length [2]. The antenna in the middle of the two monopoles is fed by a 50 microstrip wire with a tuning stub. An edge port is used to excite the antenna for modelling purposes, however a 50 Ω SMA connection would be a more useful feed. The monopole antenna designed for wireless applications and communication Networks

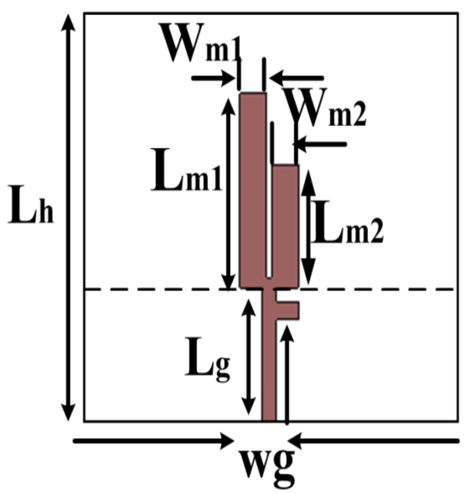

Fig.1 Antenna frond Design

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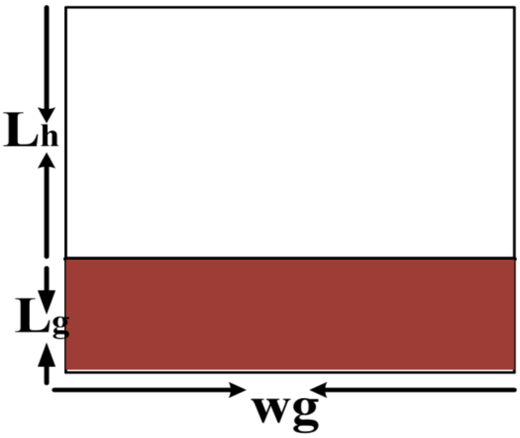

Fig.1. a) Antenna back Design

2. MIMO antenna Design Structure:

The Proposed MIMO Antennas Design of A two-port design phase, as seen in Figure 2a. While the significant mutual coupling between the two ports was evident in the simulation results of S parameters, the resonance at 1.8 GHz , 2.4 GHz, 4.5 GHz was verified. With the parameters for the transmission coefficient (S21) and reflection coefficient (S11), this is seen in Figure 2b. Figure 2c's current distribution of the MIMO antenna revealed a current path length of 40 mm , which led to The suggested Multi band and dual-element MIMO antenna system configuration

Channel capacity equation for M and N Tx and Rx antennas

$$\mathbf{C} = \mathbf{BWlog_2}\left(\mathbf{det}\left(\mathbf{I_N} + \frac{\mathbf{P_T}}{\boldsymbol{\sigma}^2\mathbf{M}}\mathbf{HH^H}\right)\right)$$

The multi band monopole antenna is installed on an inexpensive FR-4 substrate with a thickness of 1.6 mm, a relative dielectric constant of 4.4, and a loss tangent (tanδ) of 0.02. Its reduced dimension is 40 mm × 40 mm (Ls ×Ws). The incorporation of a metamaterial unit cell inserted between the two monopole antennas and a metamaterial-inspired SRR slot atop the radiating patch is necessary to achieve band notching properties. The specific measurements for the suggested SRR loaded band stop antenna, inspired by metamaterials, are shown in Table 1. The specific dimensions of the metamaterial unit cell are shown in Table 2.made on 1.6mm thickness FR-4 substrate. Two printed patch antennas are separated by distance of wg. The total area of dual –element MIMO antenna system is (wg x Lh) with spacing of 10mm closed edges of two our rings the overall size of each printed slot antenna element is (40x40)mm.

By using two monopole elements of varying lengths, this antenna is able to operate in three bands. Tripple resonance mode of operation is the result of the difference in lengths creating two distinct current paths. To excite the antenna, a 50Ω transmission feed line is utilized. There are two loops in every multi-band antenna element: an inner and an outer loop. The feed line connected the stub for improve the impedance matching. High isolation is achieved by placing the inspired metamaterial Unit cell between two antennas.

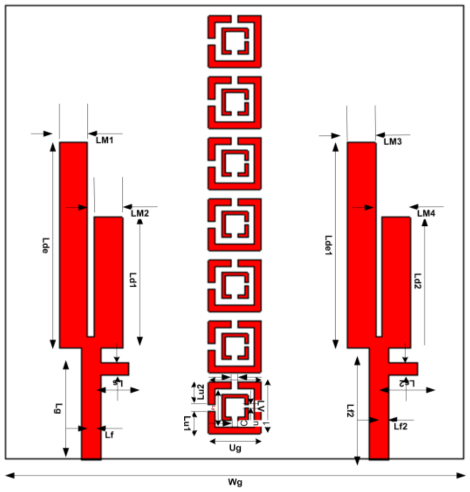

Fig.2.MIMO antenna Design

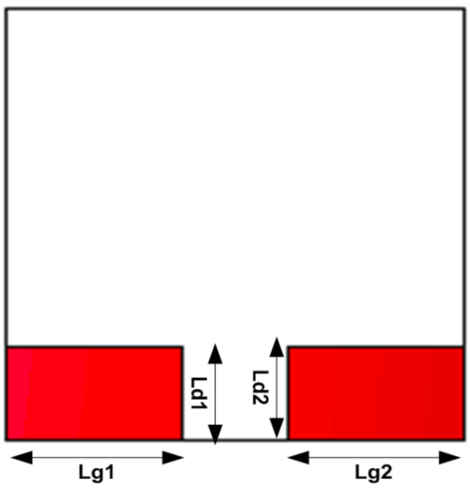

Fig.2(a) Back side of the mimo antenna

Fig2. Shows that Three different operating bands are covered by the measured 18 dB impedance bandwidths for return loss: 1.8GHz, 2.4GHz and 4.5GHz. This is capable of reaching the desired Wireless applications ISM 1800MHz and 2.4 GHz and 4.5 GHz 5G bands. That being said, at 1.8 GHz and 2.4 GHz, the maximum isolation is around 18 dB and 38 dB respectively.

$$f = \frac{c}{2L\sqrt{\varepsilon_{eff}}}$$

$$\varepsilon_{eff} = \frac{\varepsilon_r + 2}{2}$$

Where f is frequency, ε_r permeability .

Diversity Gain (DG): Measures the increase in SNR due to the use of multiplexing.

$$DG = 10\sqrt{1 - \rho_{eij}}$$

The design of the antenna parameter show in the table 1. As MIMO antenna.

Table 1. Antenna Parameters

Name	Description	Value
Lg	Ground-plane length	20 mm
Lde	Dielectric extension above ground plane edge	55 mm
Wg	Ground-plane width	45 mm
Wf	Feed-line width	3 mm
Wm1	Monopole width 1	5.363 mm
Wm2	Monopole width 2	5.363 mm
Ws	Width of the stub	3 mm
So	Monopole offset from the ground plane edge	2.3 mm
Ss	Stub offset from the ground plane edge	-60.52 µm
Sm	Spacing between the monopole elements	934.2 µm
Wb	Monopole base width	1.707 mm
ε_r	Relative permittivity	4.3
H	Substrate height	1.6 mm

Iterations steps of the Design antenna firstly design the Monopole patch antenna with lumped port step1 the Design of the antenna two different monopoles lengths connected to side by side with electrically thin substrate of PEC material. Design of substrate used in FR-4 which is inexpensive and design the antenna dully fabrication materials available on the market. Ground plane printed on back side of the substrate. The relative permittivity of the FR-4 substrate 4.3.

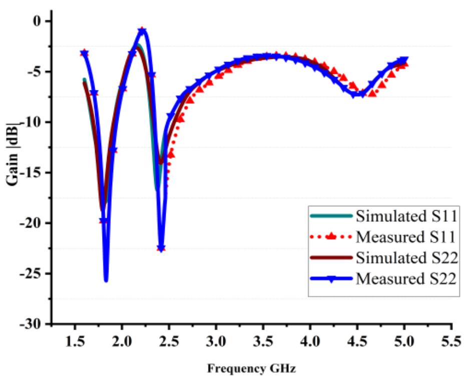

Fig.3 S-parameter simulation and Measured Result

Fig.3. Comparing the transmission and reflection coefficients of the MIMO system with metamaterials, both simulated and measured.

As per the simulation result with metamertial unit cell using s11 and s22 got the same result and good Isolation The resonante freqeucy must be good to identify Refection coefiecient antenna.

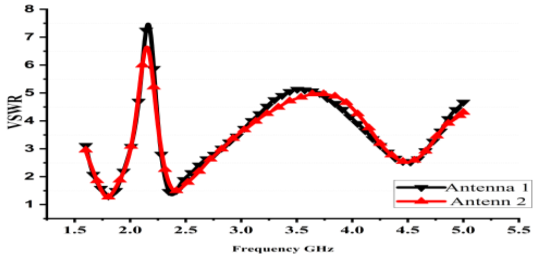

Fig.4. VSWR Results in proposed antenna

Fig.4. shows that show the findings for the voltage standing wave ratio (VSWR) and reflection coefficient for the proposed antenna's development. Figures demonstrate how the proposed antenna uses metamaterial-inspired SRR structures and slots on the radiating patch to display bands gain in 2dbi,2.5dbi.

Using the CST MWS EM solver, the suggested antenna's performance has been examined and improved. The suggested antenna is assumed to provide an omnidirectional radiation pattern and multi-band operation while remaining small in size.

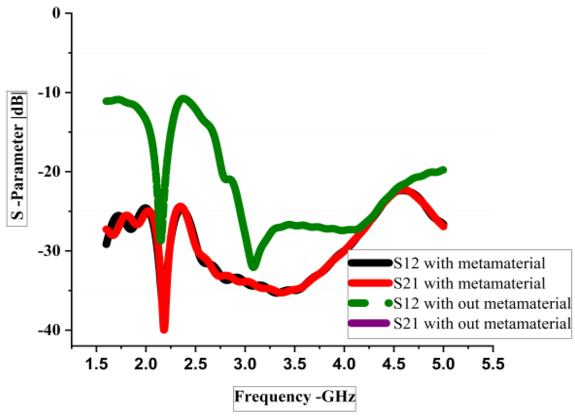

fig.5 s-parameter s21& s12.

3. .Metamerrial Strucure Unit Cell:

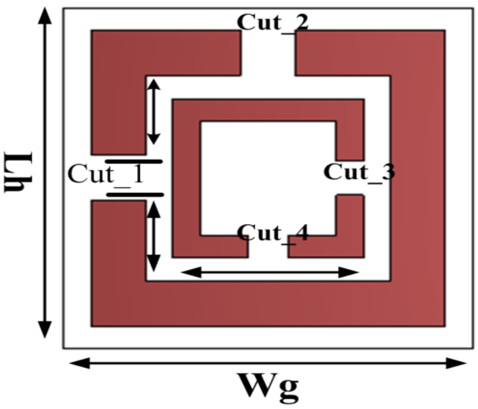

Fig.6. Metamerial unit cell.

The metamaterial-inspired SRR structure's cut_1,

Cut_2,Cut_3,Cut_4 optimization based on voltage standing wave ratio (VSWR) is show in fig.4**.** (The gap cut_1and cut_2 dimensions are changed from 1.13 mm to 1.22 mm in order to optimize the WLAN band rejection frequency. It is evident that the 5.5-4.8 GHz rejected WLAN band has a high VSWR value of 3.5, 2.4, 2.3 at the frequency of 1.8 GHz, 2.4GHz, 4.5GHz. The overall inductance and gap capacitance of the resonator structure somewhat drop as the gap values C1 and C2 of the metamaterial-inspired SRR structure grow, aiding in the WLAN's targeted rejected frequency.

To achieve the ISM band and WiMAX, the value of C3 is raised from 0.7 mm to 3mm with a 0.7mm step size. The rejected band has maximal VSWR 5.22 at frequency 2.4 GHz when the gap value is set to 0.6 mm, as can be show in fig.6 **.** The rejected band shows the highest VSWR 5.09 at 2.4 GHz.With a 0.2 mm step size increase, the value of gap C4 is changed from 2.16 mm to 2.1 mm. The circular split ring can accomplish the necessary band and the rejected band exhibits peak VSWR 3.26 when the gap value is selected as c4 2.2mm. In order to reach the higher resonance frequency.

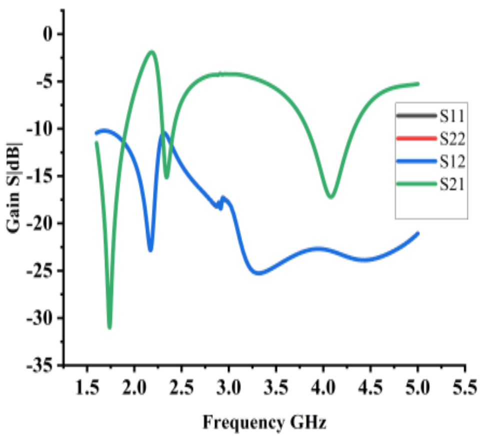

Fig.7. Unit cell s- parameter simulattion Result

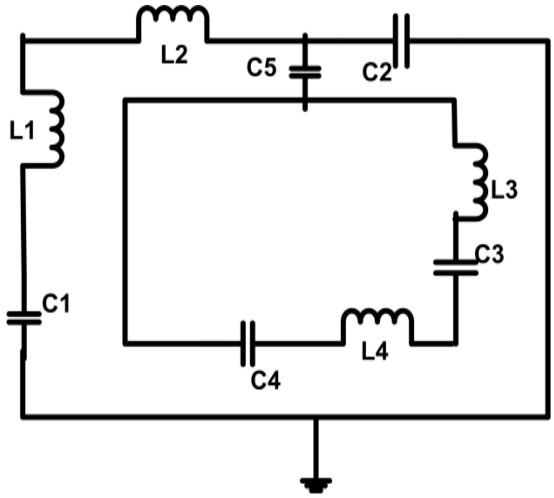

Fig.8. Unit Cell – Equalent Circuit.

Table.2 shows that the Isolation compariision of the other antennas. Different antenna frequency bands are comparable wth proposed antennas is better results and good impadnace

Table.2. comparision of Isolation table.

Ref.	**Size(mm×mm)**	**Frequency (GHz)**	**Isolation (dB)**
[11]	41×30	2.9-11.7	-20
[12]	26×55	3.1-12.3	-20
[13]	32×32	3-4.5	-15
[14]	25×30	3.1-11.3	-20
[15]	30×40	2.4 & 3.1-11.7	-15
[16]	33×35	3.1-5	-22
[17]	42×24	3.1-10.9	-15
This work	55×45	1.8-5.8	-20

4. Antenna Fabrication and Results

This section discusses the suggested antenna's simulated result and optimizes it by examining the simulated results for the voltage standing wave ratio, antenna gain, radiation pattern, and radiation efficiency, in that order. To maximize the performance of the suggested multiband antenna, a parametric research is conducted. Using CST MWS simulation software , the suggested monopole antenna is examined. The rectangular split ring resonator (SRR) is examined during the parametric analysis.

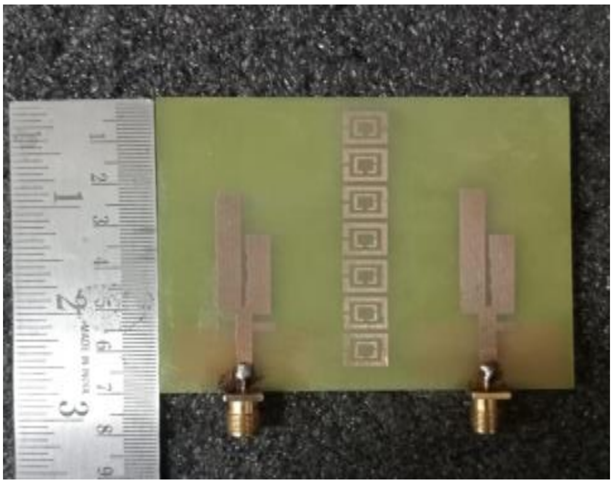

Fig.9. fabricated antenna front side

Fig.10 fabricated antenna back side

Fig.11. fabrication antenna connect to antenna chamber.

At specific frequencies of 1.8 GHz, 2.4 GHz and 4.5 GHz, simulated radiation patterns are also produced in the E-plane (phi 0°) and H-plane (phi 90°) (major planes). The correspondingly

Surface Current at Current Distribution of the antenna(Frequencies) .Fig 16, shows the current distribution of the MIMO antennafit.17 shows that the measured and simulated results of 1 dimentional.

The fig.17 shows that the farfiled results of 1.8 GHz, 2.4 GHz and 4.5 GHz. Simulated and measured results.

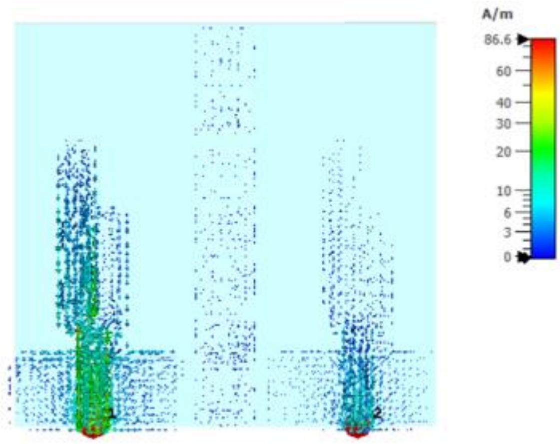

Fig .12(a). surface current at 1.8 GHz

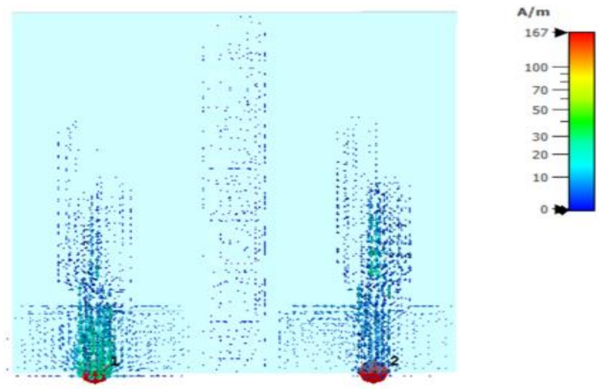

Fig.12(b).Surface current at 2.4 GHz

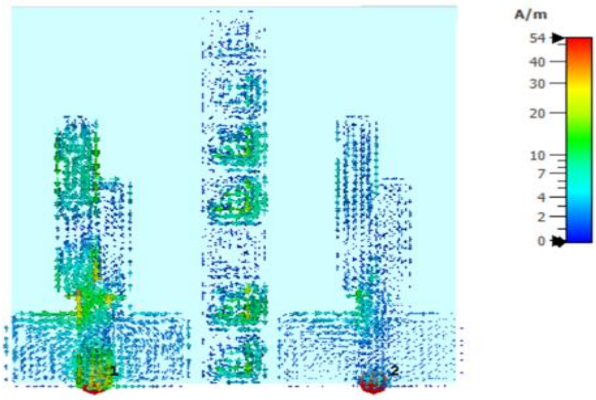

Fig.12.(c) surface current at 4.5 GHz.

Antenna- Farfiled Results

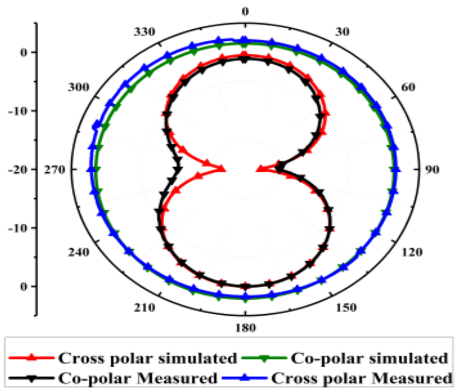

Fig.13(a).1.8 E- plane

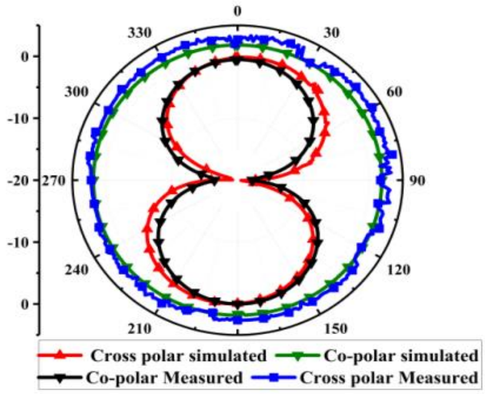

Fig.13(b).1.8 H plane

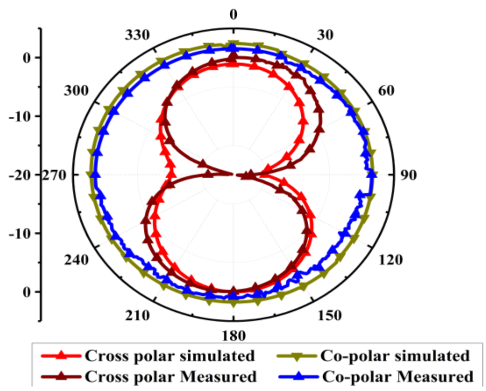

Fig.13(c).2.4 E- plane

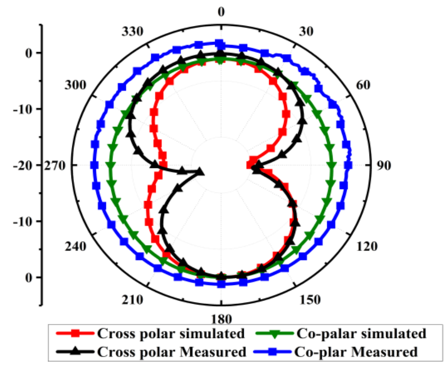

Fig.13.(d).2.4 H plane.

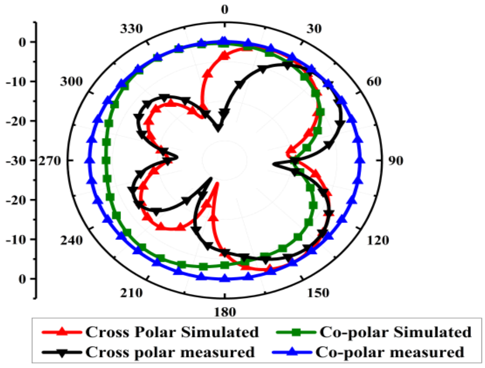

Fig.13.(e).4.5 E –plane

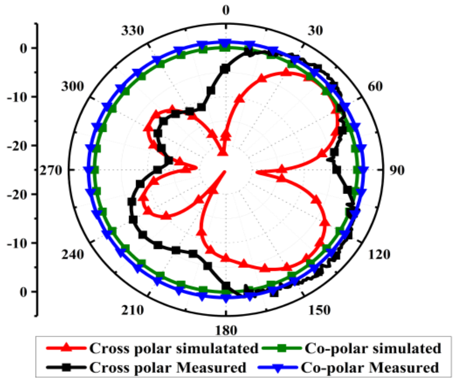

Fig.13(f).4.5 H-plane

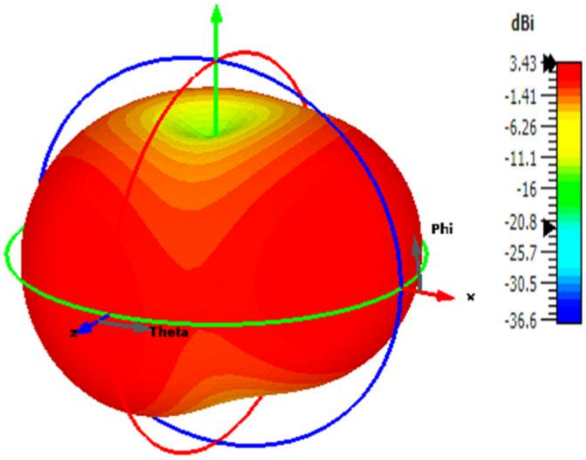

Fig.14(a).1.8 GHz antenna(1)

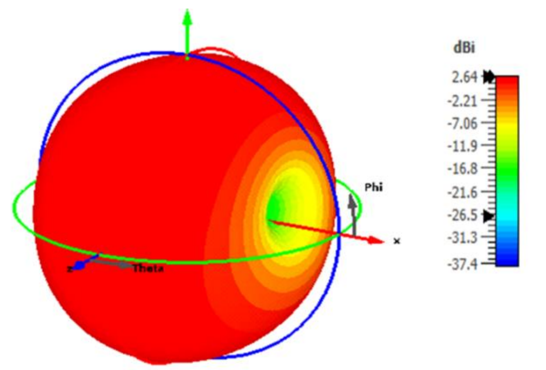

Fig.14.(b) frequency 1.8 GHz Antenna(2)

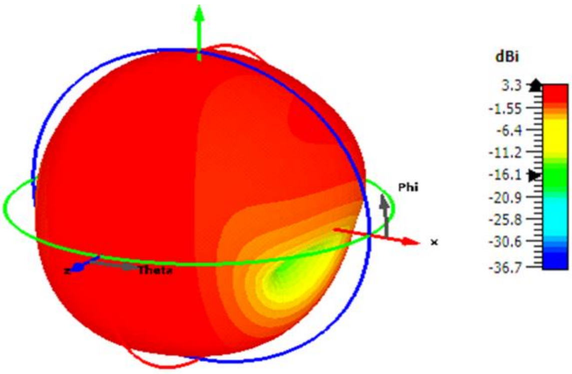

Fig.14©. frequency 2.4 GHz Antenna(1)

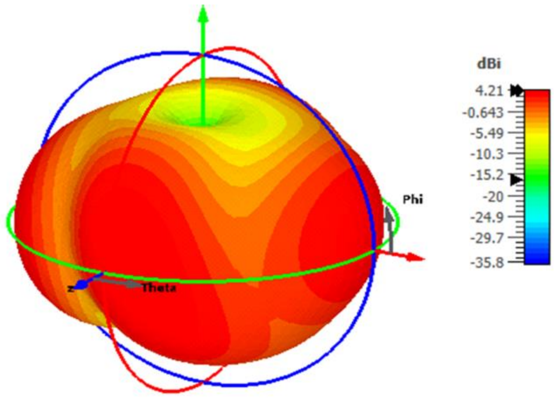

Fig.14(d). frequency 2.4 GHz Antenna(2)

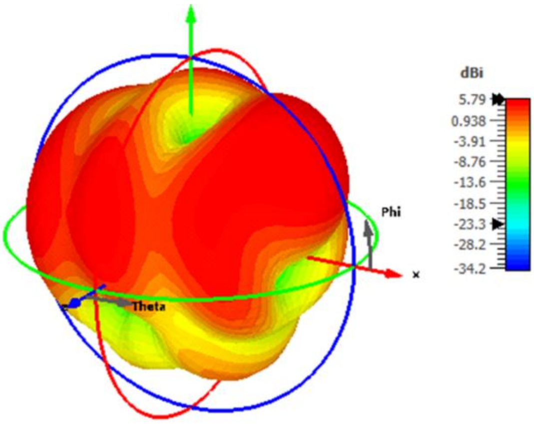

Fig.14(e).4.5 GHz antenna(1)

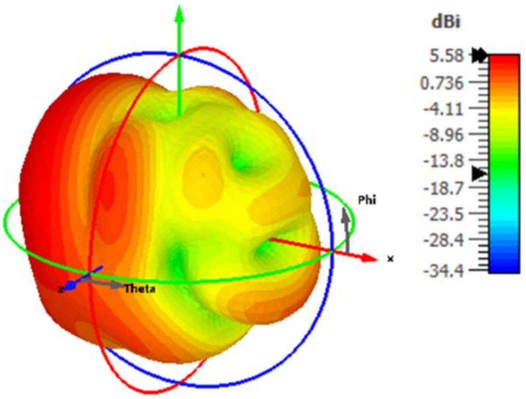

Fig.14(f)4.5 GHz antenna(2)

Fig14. A to f shows that the 3d radiation pattern of the two antennas.

5. CONCLUSION:

A split ring resonator loaded antenna with band stop characteristics that is small in size and inspired by metamaterials is suggested. The suggested antenna has frequency rejection properties and can offer a broad bandwidth ranging from 1.8GHz to 5.5GHz. The multiband created for wilress and wifi, 5G Applications bands notches are created, by etching a split ring resonator slot on top of the patch design. The recommended antenna's feed line is close to the metamaterial-inspired SRR structure, which is entrenched to achieve the WLAN band stop feature. From the parametric analysis, it is noted that by varying the size of the SRR structure and slots, the band notching at various frequencies may be individually adjusted and regulated. This antenna is small and works wonders at blocking off UWB pass band interference from existing bands (WLAN-band,WIMAX,5G Communication signal). With a peak gain of 3.2dBi, the suggested antenna shows negative gain at -28db frequencies. Furthermore, the study that is being given shows good radiation efficiency of around 80–90% over pass bands and 35%, 23%, and 45% at 1.8 GHz, 2.4 GHz, and 4.5 GHz, in that order. The measured result and the predicted outcome accord well. The suggested antenna's performance indicates that it is a good fit for wireless applications.

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